

CLAIMS

1. A sensorless control apparatus of an AC motor which separates a motor current into a magnetic flux component and a torque component based on an estimated magnetic flux position of a synchronous motor without using position and speed sensors and independently controls each of them, thereby implementing a high control performance of the synchronous motor, comprising:

a high frequency generator for superposing a high frequency signal on an estimated magnetic flux axis of the motor;

a high frequency component extractor for extracting, from a voltage or current detection signal having the same frequency component as a frequency component of the high frequency signal, an error signal of the magnetic flux position which is obtained based on a magnetic saliency of a physical quantity of the motor in a high frequency region generated by a magnetic saturation caused by a main magnetic flux or a conductor skin effect produced by a high frequency;

a magnetic flux observer for estimating a magnitude and a position of a magnetic flux from a motor input voltage, a detection current and a speed estimation value;

a first adaptive regulator for adaptively regulating an error signal of a magnetic flux position to be an output of the high frequency component extractor;

a second adaptive regulator for adaptively regulating an

error signal calculated from a magnetic flux estimation value and an error value of an output of the magnetic flux observer in the same observer;

a hybrid device for switching the first adaptive regulator at a very low speed, the first and second adaptive regulators at a low speed and the second adaptive regulator at a high speed depending on the speed; and

a speed estimator for generating a speed estimation value from an output value of the hybrid device.

2. The sensorless control apparatus of an AC motor according to claim 1, further comprising a magnetic flux regulator for regulating a magnetic flux level, regulating a magnetic saliency of a physical quantity of the motor in a high frequency region and regulating an efficiency;

an estimated error corrector for correcting an estimated error made in an estimated magnetic flux, an estimated rotor speed and an estimated rotor position;

a magnetic flux position calculator for calculating a position of a magnetic flux from the magnetic flux estimated from the magnetic flux observer;

a current controller for separating a detection current into a magnetic flux direction component and a torque component by using an estimated magnetic flux position, feeding back each of them and comparing the magnetic flux direction component with

a current command value of the torque component, thereby carrying out a current control in such a manner that each deviation is set to be zero;

a speed controller for comparing an estimated speed with a command speed to execute a speed control in such a manner that a deviation thereof is set to be zero, thereby outputting a torque command value or a current command value corresponding to a torque command; and

an initial magnetic pole position estimator for estimating an initial magnetic pole position before starting.

3. The sensorless control apparatus of an AC motor according to claim 1, wherein the high frequency generator includes a device for regulating a high frequency signal to be superposed depending on a rotating speed of a magnetic flux or a rotor speed.

4. The sensorless control apparatus of an AC motor according to claim 1, wherein the high frequency generator superposes a high frequency signal on a voltage command value.

5. The sensorless control apparatus of an AC motor according to claim 1, wherein the high frequency generator superposes a high frequency signal on a current command value.

6. The sensorless control apparatus of an AC motor according to claim 1, wherein the magnetic flux observer has a function of removing the high frequency signal from a motor input voltage depending on an output frequency or a speed.

7. The sensorless control apparatus of an AC motor according to claim 1, wherein an error signal of a magnetic flux position obtained in the high frequency component extractor is based on an impedance or an admittance in a high frequency region which is superposed.

8. The sensorless control apparatus of an AC motor according to claim 1, wherein the hybrid device has a function of removing an output of the second adaptive regulator in a very low speed region including a zero speed and has a function of removing an output of the first adaptive regulator in middle and high speed regions.

9. The sensorless control apparatus of an AC motor according to claim 1, wherein the speed estimator adaptively estimates a speed in order to set an error signal to be an output value of the hybrid device to be zero.

10. The sensorless control apparatus of an AC motor according to claim 2, wherein the magnetic flux regulator regulates a magnetic flux level into a portion in which a characteristic of the motor, that is, a magnetic saliency of a physical quantity of the motor in a high frequency region can be maintained and a high efficiency can be obtained, and the estimated error corrector corrects an estimated magnetic flux, an estimated rotor speed and an estimated rotor position error which are generated when the magnetic saliency at the high frequency is reduced.

11. The sensorless control apparatus of an AC motor according to claim 2, wherein the current controller has a function of removing a superposed high frequency component from a current which is fed back when the high frequency signal to be superposed is a voltage and a response frequency of the controller is set to be higher than a superposed frequency component when the high frequency signal to be superposed is a current.

12. The sensorless control apparatus of an AC motor according to claim 2, wherein the initial magnetic pole position estimator has a signal processing portion for extracting at least one frequency of harmonics which are n th power of 2 ($N = -1, 1, 2, 3, \dots, n$) of the superposed high frequency and serves to discriminate an N or S pole of a magnetic pole.

13. A sensorless control method of an AC motor which separates a motor current into a magnetic flux component and a torque component based on an estimated magnetic flux position of a synchronous motor without using position and speed sensors and independently controls each of them, thereby implementing a high control performance of the synchronous motor, comprising:

means for superposing a high frequency signal on an estimated magnetic flux axis of the motor;

means for extracting, from a voltage or current detection signal having the same frequency component as a frequency component of the high frequency signal, an error signal of the

magnetic flux position obtained based on a magnetic saliency of a physical quantity of the motor in a high frequency region generated by a magnetic saturation caused by a main magnetic flux or a conductor skin effect produced by a high frequency;

means for estimating a magnitude and a position of a magnetic flux from a motor input voltage, a detection current and a speed estimation value through a magnetic flux observer;

first adaptive rule means for adaptively regulating an error signal of a magnetic flux position to be an output of the high frequency component extractor;

second adaptive rule means for adaptively regulating an error signal calculated from a magnetic flux estimation value and an error value of an output of the magnetic flux observer in the same observer;

means for switching the first and second adaptive rule means depending on a speed; and

means for estimating a speed from an output signal of the adaptive rule means.

14. The sensorless control method of an AC motor according to claim 13, further comprising means for regulating a magnetic flux in order to maintain a magnetic saliency of a physical quantity of the motor in a high frequency region and to hold a high efficiency;

an estimated error corrector for correcting an estimated

error made in an estimated magnetic flux, an estimated rotor speed and an estimated rotor position;

means for calculating a position of a magnetic flux from a magnetic flux vector estimated from the magnetic flux observer;

means for separating a detection current into a magnetic flux direction component and a torque component by using an estimated magnetic flux position, feeding back each of them and comparing the magnetic flux direction component with a current command value of the torque component, thereby carrying out a current control in such a manner that each deviation is set to be zero;

means for comparing an estimated speed with a command speed to execute a speed control in such a manner that a deviation thereof is set to be zero, thereby outputting a torque command value or a current command value corresponding to a torque command; and

initial magnetic pole estimating means for discriminating an N or S pole of a magnetic pole before starting.

15. The sensorless control method of an AC motor according to claim 13, wherein the means for switching the adaptive rule means depending on a speed has a function of removing an output signal of the second adaptive rule means in a very low speed region including a zero speed and a zero frequency and has a function of removing an output signal of the first adaptive rule

means in middle and high speed regions.

16. The sensorless control method of an AC motor according to claim 13, wherein the means for extracting an error signal of a magnetic flux position obtained based on a magnetic saliency of a physical quantity of the motor uses the physical quantity of the motor including a motor input voltage command value and a detection current or a detection voltage and the detection current.

17. The sensorless control method of an AC motor according to claim 13, wherein the means for superposing a high frequency has means for regulating a high frequency signal to be superposed depending on an output frequency or a speed.

18. The sensorless control method of an AC motor according to claim 14, wherein the means for regulating a magnetic flux serves to regulate a magnitude of a magnetic flux in order to obtain a magnetic saliency of a physical quantity of the motor in such a manner that a magnetic flux position can be detected depending on a peculiar characteristic to the motor at a very low speed including a zero speed and a zero frequency and an error of a magnetic flux position which is made by a load is regulated in a magnetic flux position on which a high frequency is to be superposed, the regulating means carrying out a regulation through an estimated error and a stator (primary) current or a command current.

19. The sensorless control method of an AC motor according to claim 14, wherein the initial magnetic pole estimating means has a signal processing portion for extracting at least one frequency of harmonics which are n th power of 2 ($N = -1, 1, 2, 3, \dots, n$) of the superposed high frequency and serves to discriminate an N or S pole of a magnetic pole.

20. A sensorless control apparatus of an AC motor which separates a motor current into a magnetic flux component and a torque component based on an estimation value of a magnetic flux position of an induction motor without using a speed sensor and independently controls each of them, thereby implementing a high control performance of the induction motor, comprising:

- a high frequency generator for superposing a high frequency signal on an estimated magnetic flux axis of the motor;

- a high frequency component extractor for extracting, from a voltage or current detection signal having the same frequency component as a frequency component of the high frequency signal, an error signal of the magnetic flux position obtained based on a magnetic saliency of a physical quantity of the motor in a high frequency region generated by a magnetic saturation caused by a main magnetic flux or a conductor skin effect produced by a high frequency;

- a magnetic flux observer for estimating a magnitude and a position of a magnetic flux from a motor input voltage, a

detection current and a speed estimation value;

a third adaptive regulator for adaptively regulating an error signal of a magnetic flux position to be an output of the high frequency component extractor;

a fourth adaptive regulator for adaptively regulating an error signal calculated from a magnetic flux estimation value and an error value of an output of the magnetic flux observer in the same observer;

a hybrid device for switching the third adaptive regulator at a very low speed, the third and fourth adaptive regulators at a low speed and the fourth adaptive regulator at a high speed depending on the speed; and

a speed estimator for generating a speed estimation value from an output value of the hybrid device.

21. The sensorless control apparatus of an AC motor according to claim 20, further comprising a magnetic flux regulator for regulating a magnetic flux command and a magnetic flux position on which a high frequency signal is to be superposed in order to adjust a magnetic saliency of a physical quantity of the motor in a high frequency region;

a magnetic flux position calculator for calculating a position of a magnetic flux from the magnetic flux estimated from the magnetic flux observer;

a current controller for separating a detection current

into a magnetic flux direction component and a torque component by using the calculated magnetic flux position, feeding back each of them and comparing the magnetic flux direction component with a current command value of the torque component, thereby carrying out a current control in such a manner that each deviation is set to be zero; and

a speed controller for comparing an estimated speed with a command speed to execute a speed control in such a manner that a deviation thereof is set to be zero, thereby outputting a torque command value or a current command value corresponding to a torque command.

22. The sensorless control apparatus of an AC motor according to claim 20, wherein the high frequency generator includes a device for regulating a high frequency signal to be superposed depending on an output frequency or a speed.

23. The sensorless control apparatus of an AC motor according to claim 20, wherein the high frequency generator superposes a high frequency signal on a voltage command value.

24. The sensorless control apparatus of an AC motor according to claim 20, wherein the high frequency generator superposes a high frequency signal on a current command value.

25. The sensorless control apparatus of an AC motor according to claim 20, wherein the magnetic flux observer has a function of removing the high frequency signal from a motor input voltage

depending on an output frequency or a speed.

26. The sensorless control apparatus of an AC motor according to claim 20, wherein an error signal of a magnetic flux position obtained in the high frequency component extractor is based on an impedance or an admittance in a high frequency region which is superposed.

27. The sensorless control apparatus of an AC motor according to claim 20, wherein the hybrid device has a function of removing an output of the fourth adaptive regulator in a very low speed region including a zero speed and a zero frequency, and has a function of removing an output of the third adaptive regulator in middle and high speed regions.

28. The sensorless control apparatus of an AC motor according to claim 20, wherein the speed estimator adaptively estimates a speed in order to set an error signal to be an output value of the hybrid device to be zero.

29. The sensorless control apparatus of an AC motor according to claim 21, wherein the magnetic flux regulator has a function of regulating a magnitude of a magnetic flux in order to obtain a magnetic saliency of a physical quantity of the motor in such a manner that a magnetic flux position can be detected depending on a peculiar characteristic to the motor and a function of regulating an error of a magnetic flux position which is made by a load in a magnetic flux position on which a high frequency

is to be superposed.

30. The sensorless control apparatus of an AC motor according to claim 21, wherein the current controller has a function of removing a superposed frequency component from a current fed back when the high frequency signal to be superposed is a voltage, and a response frequency of the controller is set to be higher than the superposed frequency component when the high frequency signal to be superposed is a current.

31. A sensorless control method of an AC motor which separates a motor current into a magnetic flux component and a torque component based on an estimation value of a magnetic flux position of an induction motor without using a speed sensor and independently controls each of them, thereby implementing a high control performance of the induction motor, comprising:

means for superposing a high frequency signal on an estimated magnetic flux axis of the motor;

means for extracting, from a voltage or current detection signal having the same frequency component as a frequency component of the high frequency signal, an error signal of the magnetic flux position obtained based on a magnetic saliency of a physical quantity of the motor in a high frequency region generated by a magnetic saturation caused by a main magnetic flux or a conductor skin effect produced by a high frequency;

means for estimating a magnitude and a position of a

magnetic flux from a motor input voltage, a detection current and an estimated speed through a magnetic flux observer;

third adaptive rule means for adaptively regulating an error signal of a magnetic flux position to be an output of the high frequency component extractor;

fourth adaptive rule means for adaptively regulating an error signal calculated from a magnetic flux estimation value and an error value of an output of the magnetic flux observer in the same observer;

means for switching the first and second adaptive rule means depending on a speed or an output frequency; and

means for estimating a speed from an output signal of the adaptive rule means.

32. The sensorless control method of an AC motor according to claim 31, further comprising means for regulating a magnetic flux in order to adjust a magnetic saliency of a physical quantity of the motor in a high frequency region;

means for calculating a position of a magnetic flux from the magnetic flux estimated from the magnetic flux observer;

means for separating a detection current into a magnetic flux direction component and a torque component by using the calculated magnetic flux position, feeding back each of them and comparing the magnetic flux direction component with a current command value of the torque component, thereby carrying

out a current control in such a manner that each deviation is set to be zero; and

means for comparing an estimated speed with a command speed to execute a speed control in such a manner that a deviation thereof is set to be zero, thereby outputting a torque command value or a current command value corresponding to a torque command.

33. The sensorless control method of an AC motor according to claim 31, wherein the means for switching the adaptive rule means has a function of removing an output signal of the fourth adaptive rule means in a very low speed region including a zero speed and a zero frequency and a function of removing an output signal of the third adaptive rule means in middle and high speed regions.

34. The sensorless control method of an AC motor according to claim 31, wherein the means for extracting an error signal of a magnetic flux position obtained based on a magnetic saliency of a physical quantity of the motor and the means for estimating a magnitude and a position of a magnetic flux by a magnetic flux observer use the physical quantity of the motor including a motor input voltage command value and a detection current or a detection voltage and the detection current.

35. The sensorless control method of an AC motor according to claim 31, wherein the means for superposing a high frequency

has means for regulating a high frequency signal to be superposed depending on an output frequency or a speed.

36. The sensorless control method of an AC motor according to claim 32, wherein the regulating means serves to regulate a magnitude of a magnetic flux in order to obtain a magnetic saliency of a physical quantity of the motor in such a manner that a magnetic flux position can be detected depending on a peculiar characteristic to the motor at a very low speed including a zero speed and a zero frequency and an error of a magnetic flux position which is made by a load is regulated in a magnetic flux position on which a high frequency is to be superposed, the regulating means depending on an estimated speed and a stator (primary) current or a command current.